The T-ρ coexistence curve of nuclear matter: ISiS results

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In Fisher's droplet model [1] a non-ideal fluid is approximated by an ideal gas of droplets. Thus, summing over An_A, the normalized yield of droplets of size A multiplied by A, gives the, density and the reduced density is:

$$\frac{\rho}{\rho_c} = \frac{\sum An_A(\Delta\mu, E_{Coul}, T)}{\sum An_A(\Delta\mu, E_{Coul}, T_c)}. \quad (1)$$

With $\Delta\mu$ and E_{Coul} set to 0 in the numerator and $\Delta\mu$ and E_{Coul} set to 0 with T set to T_c in the denomenator, Eq. (1) gives the vapor branch of the coexistence curve of finite nuclear matter. Figure 1 show the results from an analysis of the ISiS fragment yields of 8 GeV/c π + Au [1].

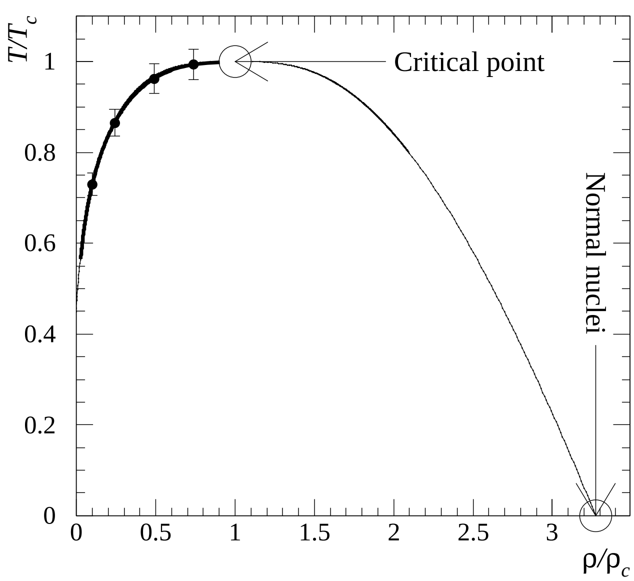

Figure 1: The reduced density-temperature phase diagram: the thick curve shows the calculated low density branch of the coexistence curve, the points show selected calculated errors and the thin curves show a fit to and reflection of Eq. (2).

Following the work with simple fluids it is possible to determine the liquid branch as well: empirically, the ρ/ρ_c-T/T_c coexistence curves of several fluids can be fit with the function:

$$\frac{\rho_{l,v}}{\rho_c} = 1 + b_1(1 - \frac{T}{T_c}) \pm b_2(1 - \frac{T}{T_c})^{\beta} \quad (2)$$

where the parameter b_2 is positive (negative) for the liquid ρ_l (vapor ρ_v) branch. Using Fisher's droplet model, β can be determined from τ and σ:

$$\beta = \frac{\tau - 2}{\sigma}. \quad (3)$$

For this work $\beta = 0.33 \pm 0.25$[1]. Using this value of β and fitting the coexistence curve with Eq. (2) one obtains estimates of the vapor branch of the coexistence curve and changing the sign of b_2 gives the liquid branch, thus yielding the full T-ρ coexistence curve of finite nuclear matter.

From Fig. 1 it is possible to make an estimate of the density at the critical point ρ_c. Assuming that normal nuclei exist at the $T = 0$ point of the ρ_l branch of the coexistence curve, then using the parameterization of the coexistence curve in Eq. (2) gives $\rho_c \sim 0.3\rho_0$.

The critical compressibility factor $C_c^F = p_c/T_c\rho_c$ can also be determined in a straightforward manner from:

$$C_c^F = \frac{\sum n_A(\Delta\mu = 0, E_{Coul} = 0, T_c)}{\sum An_A(\Delta\mu = 0, E_{Coul} = 0, T_c)}. \quad (4)$$

Performing these sums gives $C_c^F = 0.25 \pm 0.06$, in agreement with the values for several fluids. Using $T_c = 6.7 \pm 0.2$ MeV [1] and ρ_c from above in combination with C_c^F gives a critical pressure of $p_c \sim 0.07$ MeV / fm^3.

References

[1] J. B. Elliott *et al.*, Phys. Rev. Lett. **88**, 042701 (2002).